The PAH hypothesis after 25 years

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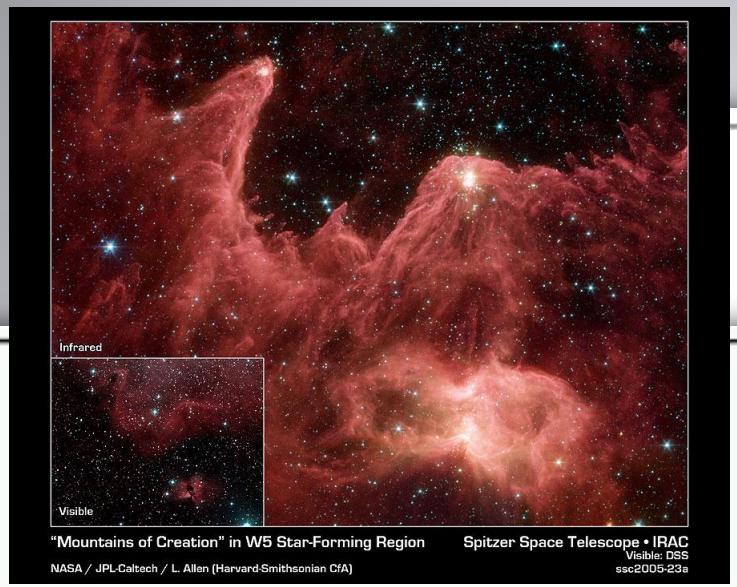
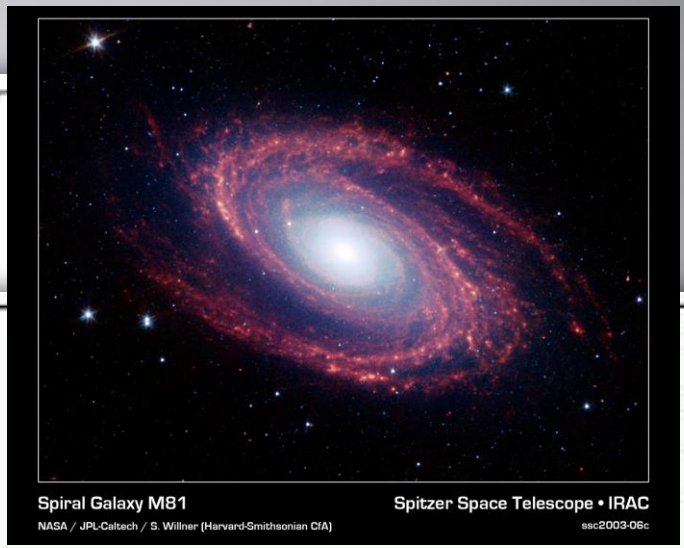
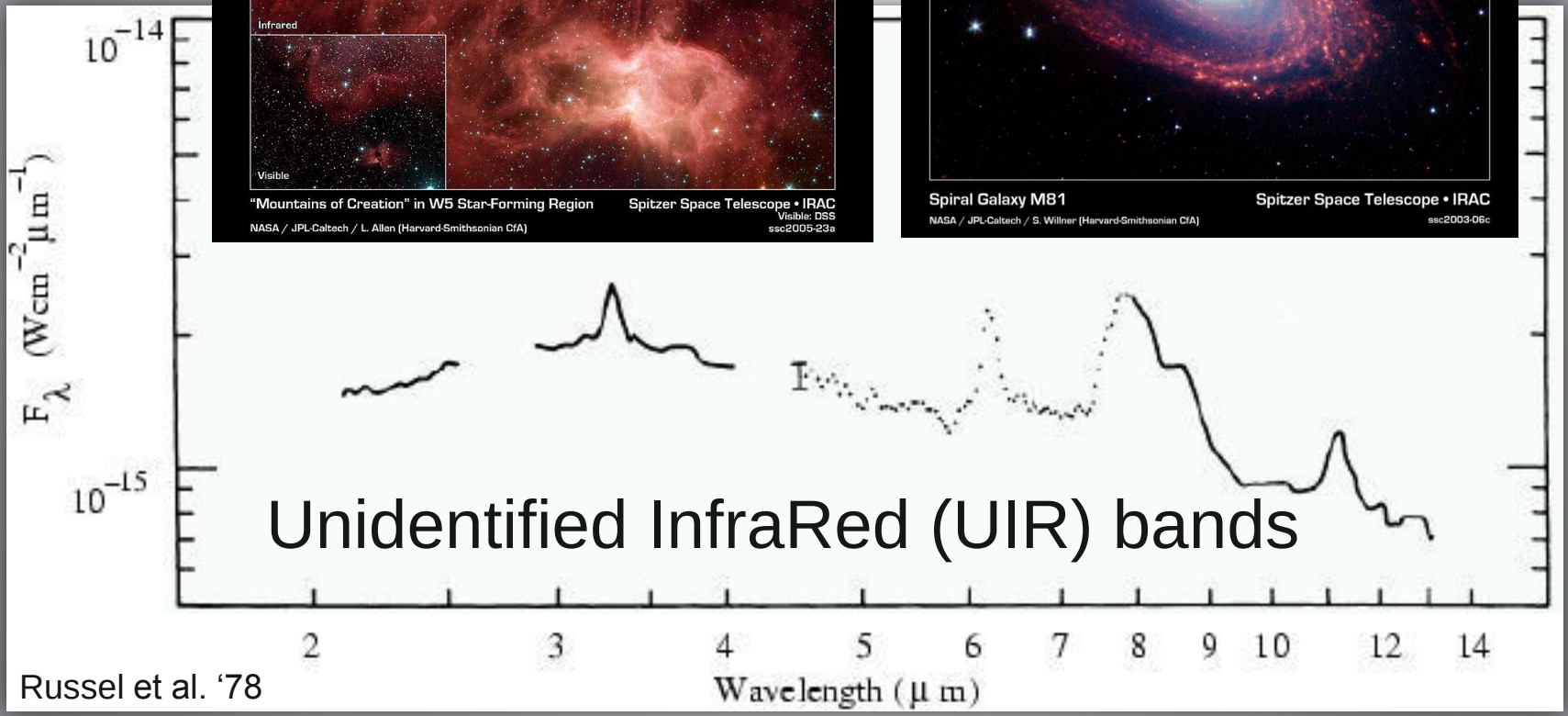
Summary

- PAH hypothesis
- Rich PAH spectrum
- Variations depend on object type, local conditions
- Variations reflect change in composition of the carriers
- PAH toolbox

Discovery





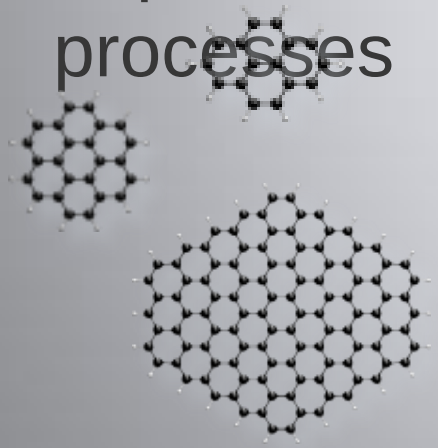


Unidentified InfraRed (UIR) bands

Russel et al. ‘78

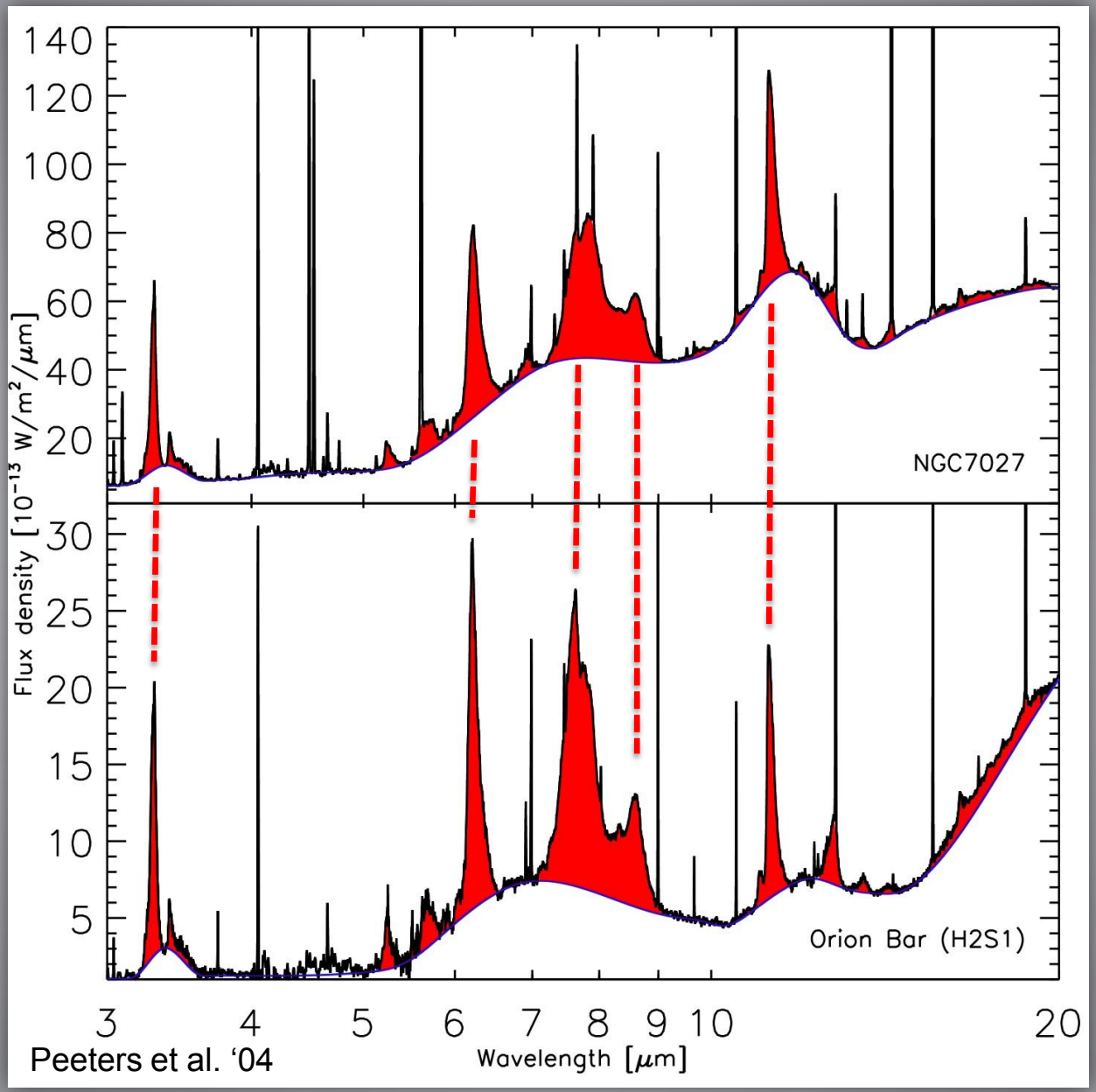
PAH hypothesis

- UIR bands due to vibrational emission of Polycyclic Aromatic Hydrocarbons (PAHs) upon absorption of UV photons
- Large fraction of the available Carbon in PAHs (~5%)
- Important in various physical and chemical processes



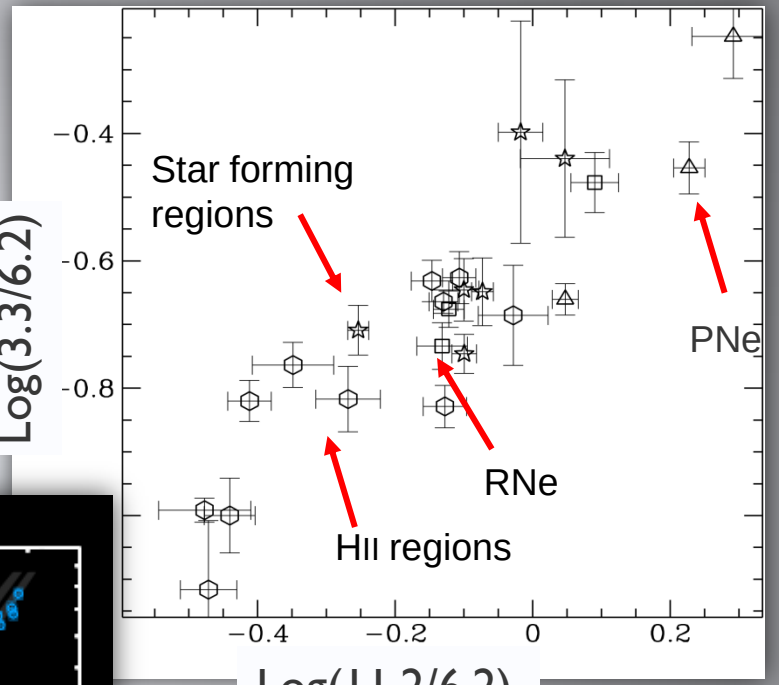
NASA Ames Astrochemistry Laboratory

Richness of the PAH spectrum

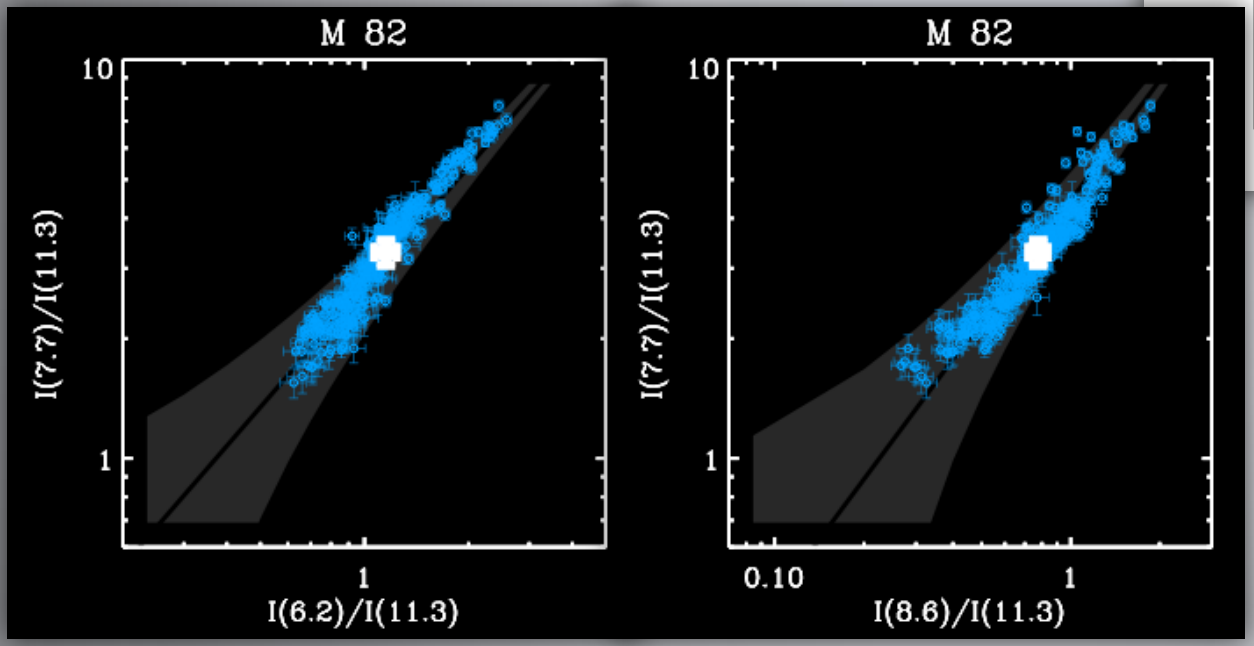


PAH intensities

- Variation in relative strength
  - depend on object type
  - vary within extended sources



Hony et al. '01



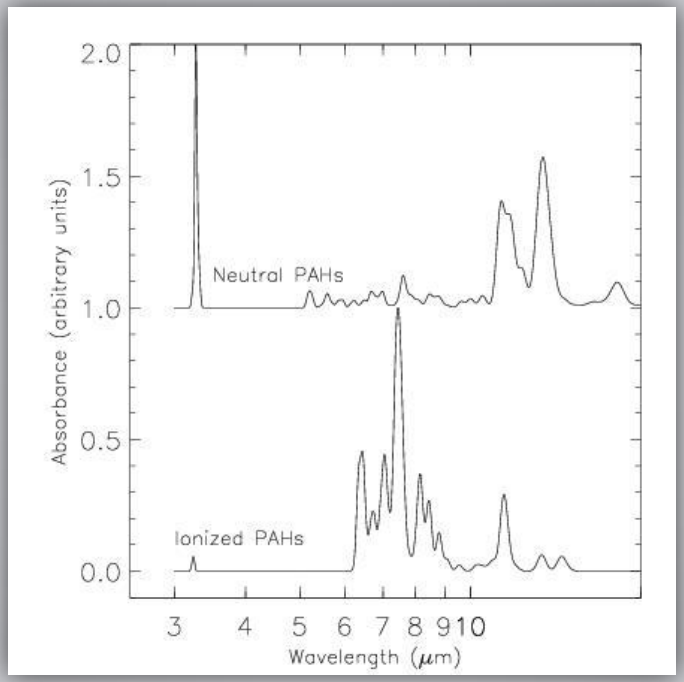
Galliano et al. '08

- families of bands:

  3.3, 11.2 vs. 6.2, 7.7, 8.6, 12.7

PAH intensities vs. lab/theory

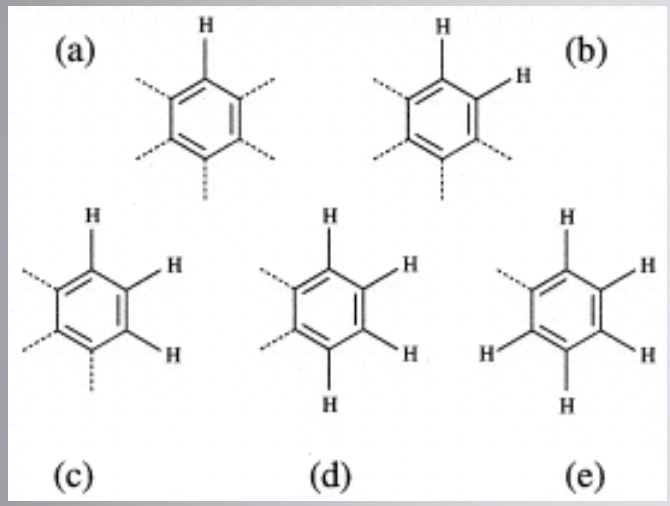
- Charge: 3.3 & 11.2 neutrals – 6.2, 7.7 & 8.6 ions

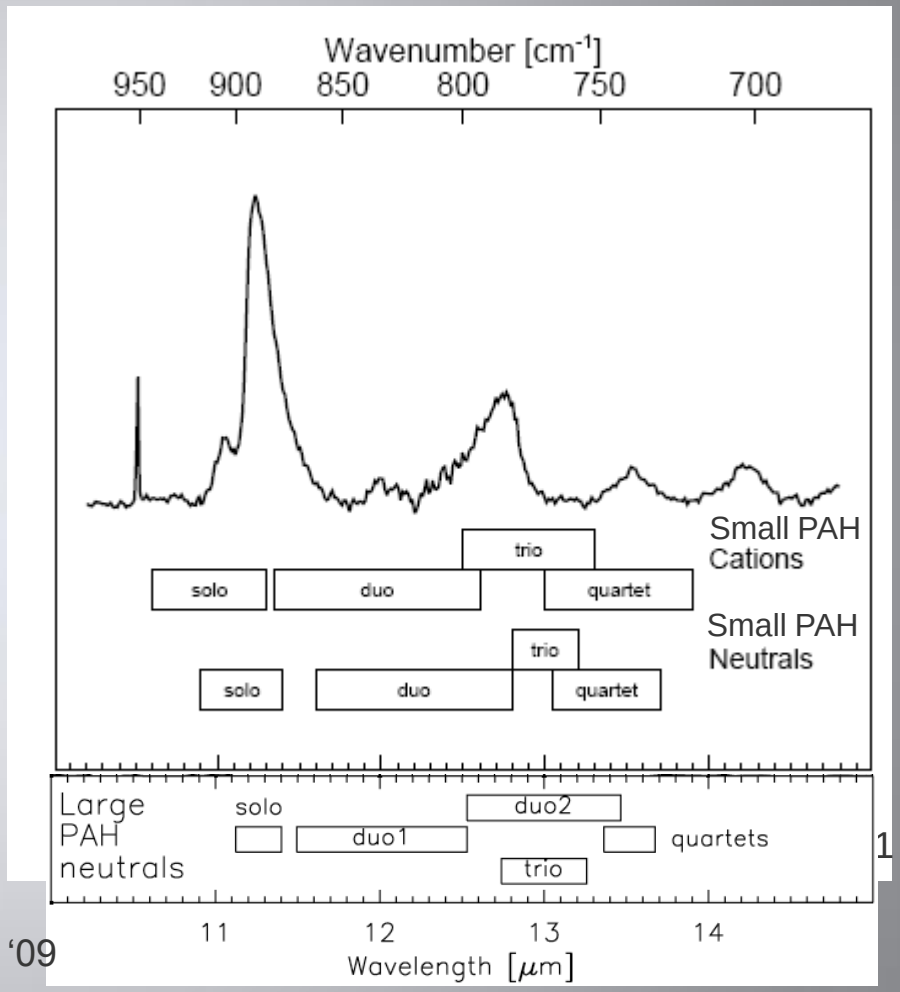


Allamandola et al. ‘99

PAH intensities vs. lab/theory

- Molecular edge structure:





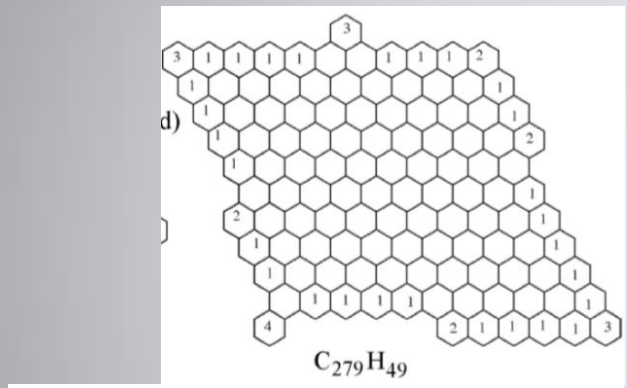
Honyet al. ’01, Bauschlicher et al ‘09

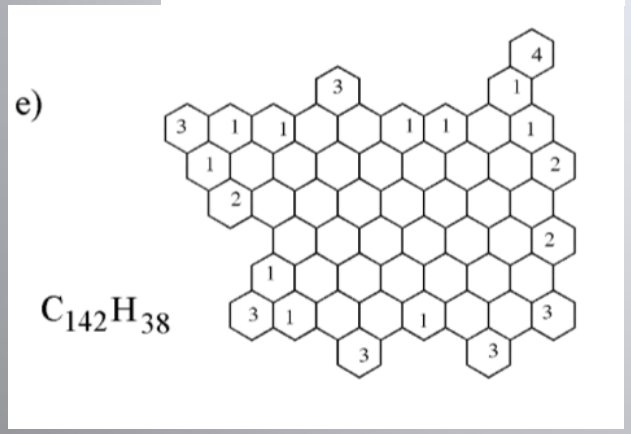
PAH intensities vs. lab/theory

- Molecular edge structure:

PNe: compact with long smooth edges

HII regions: irregular edge structure





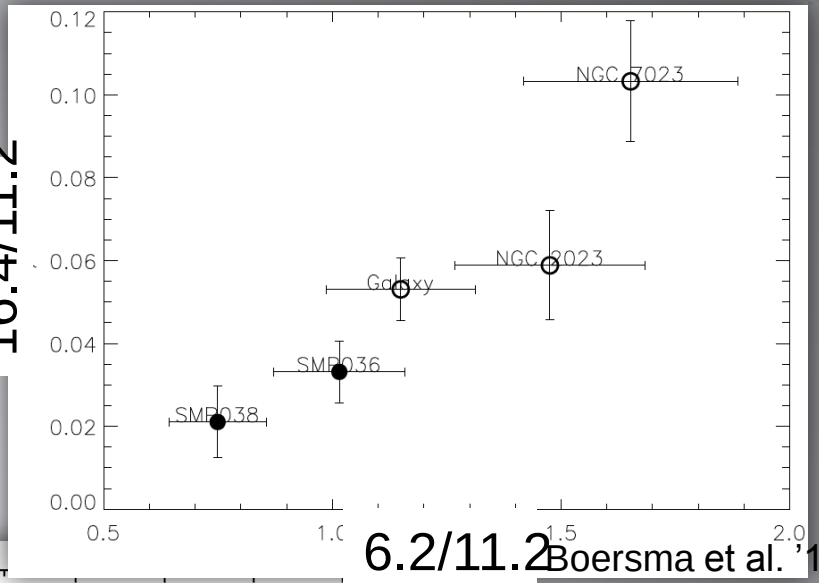
Honyet al. ’01, Bauschlicher et al. ‘09

Planetary Nebula

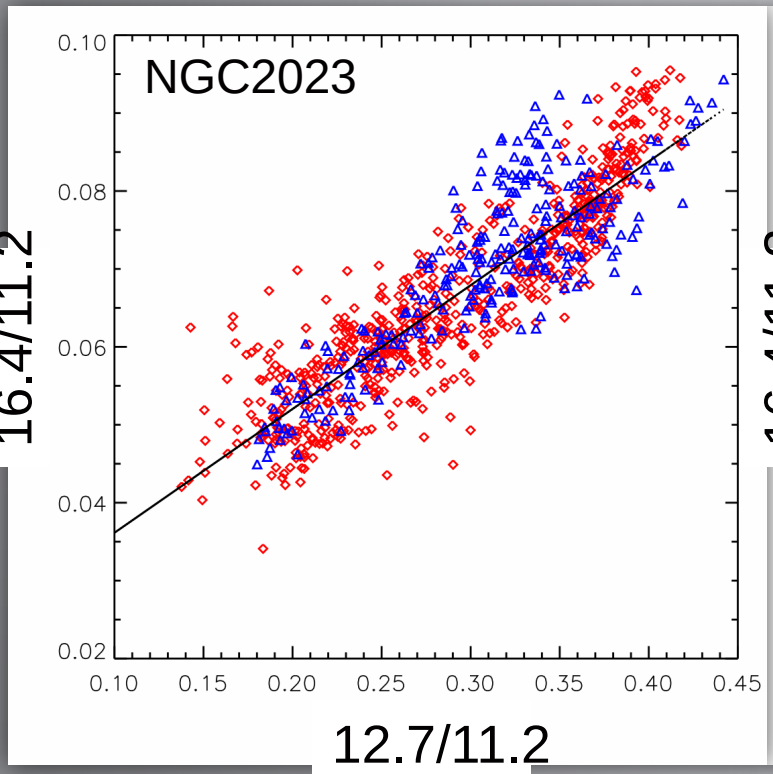
HII regions

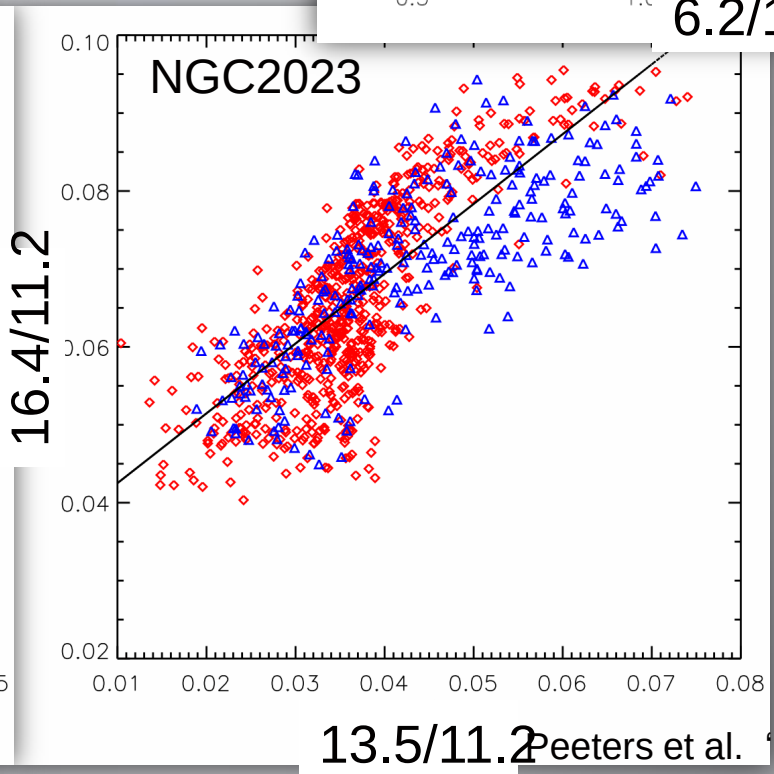
PAH intensities

- Extend to weaker bands …



Boersma et al. '1

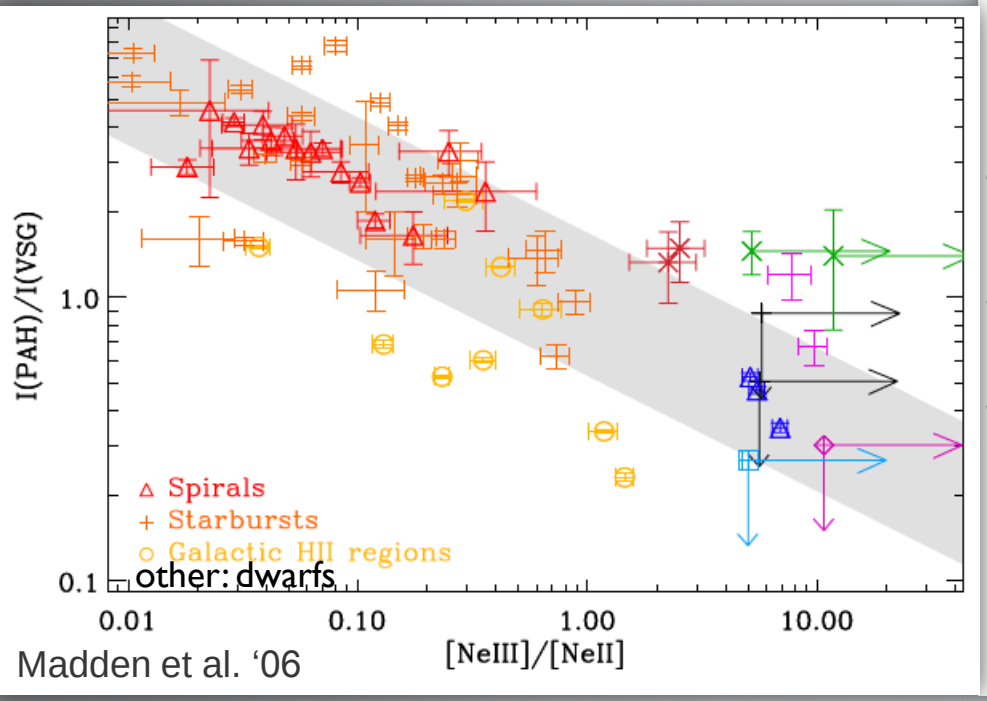




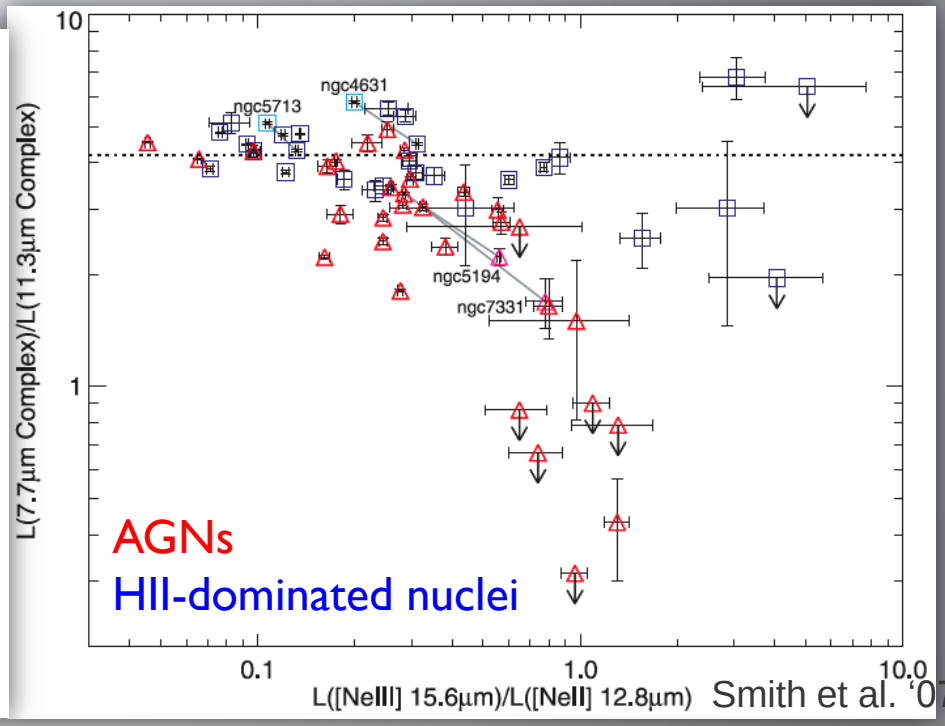
Peeters et al. '11

PAH intensities

- Dependence on:
  - Hardness of radiation field
  - Metallicity



Madden et al. '06



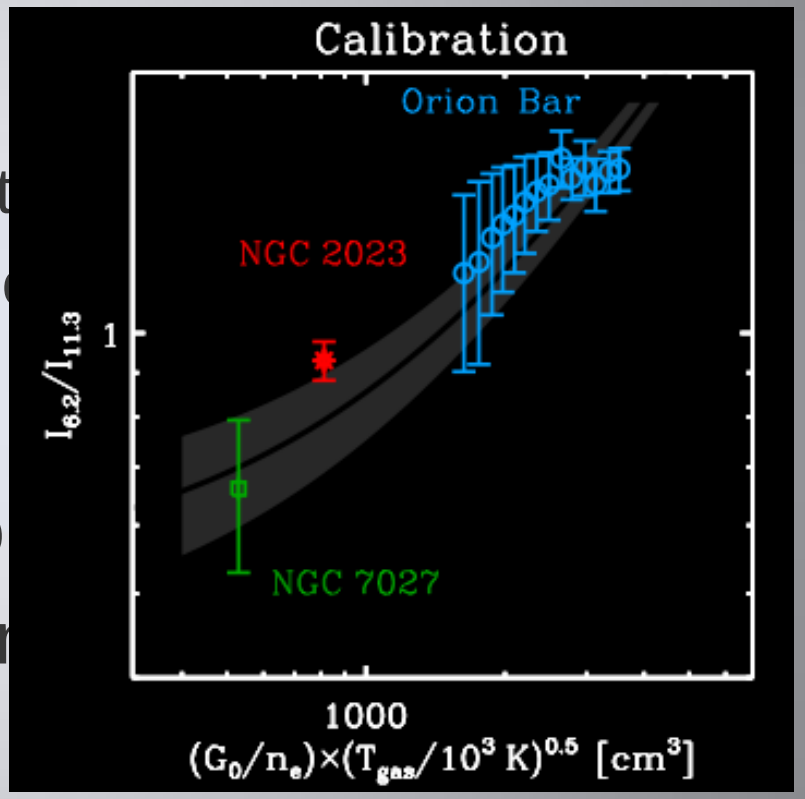
Smith et al. '07

PAH toolbox

- Empirical calibration of PAH bands
- Charge of PAHs:
  - Rate of ionization & recombinat
  - Determine from other diagnosti
    (e.g. PDR models)
- Goal: PAHs as diagnostic too
  for the local physical conditio

Galliano et al. ‘08, Berné et al. ’09

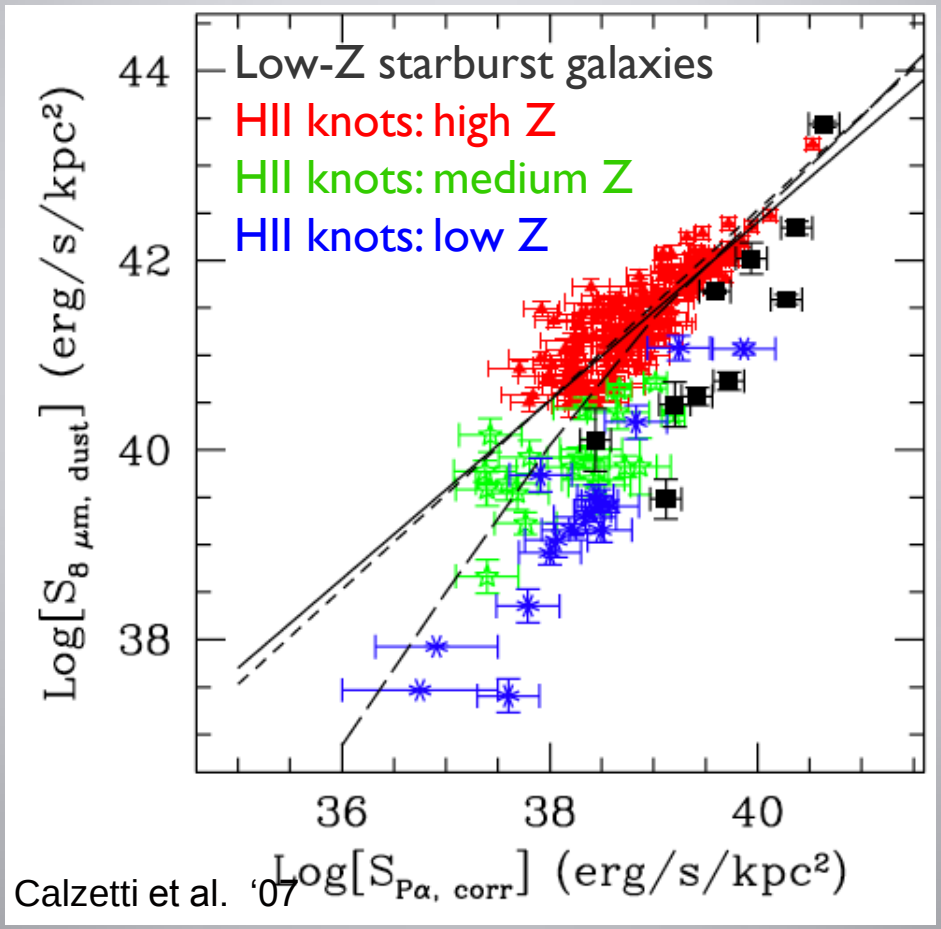
Many future Herschel papers



Galliano et al. ‘08

PAH toolbox

- Tracer of star formation
- Tool to distinguish between AGN vs. starburst

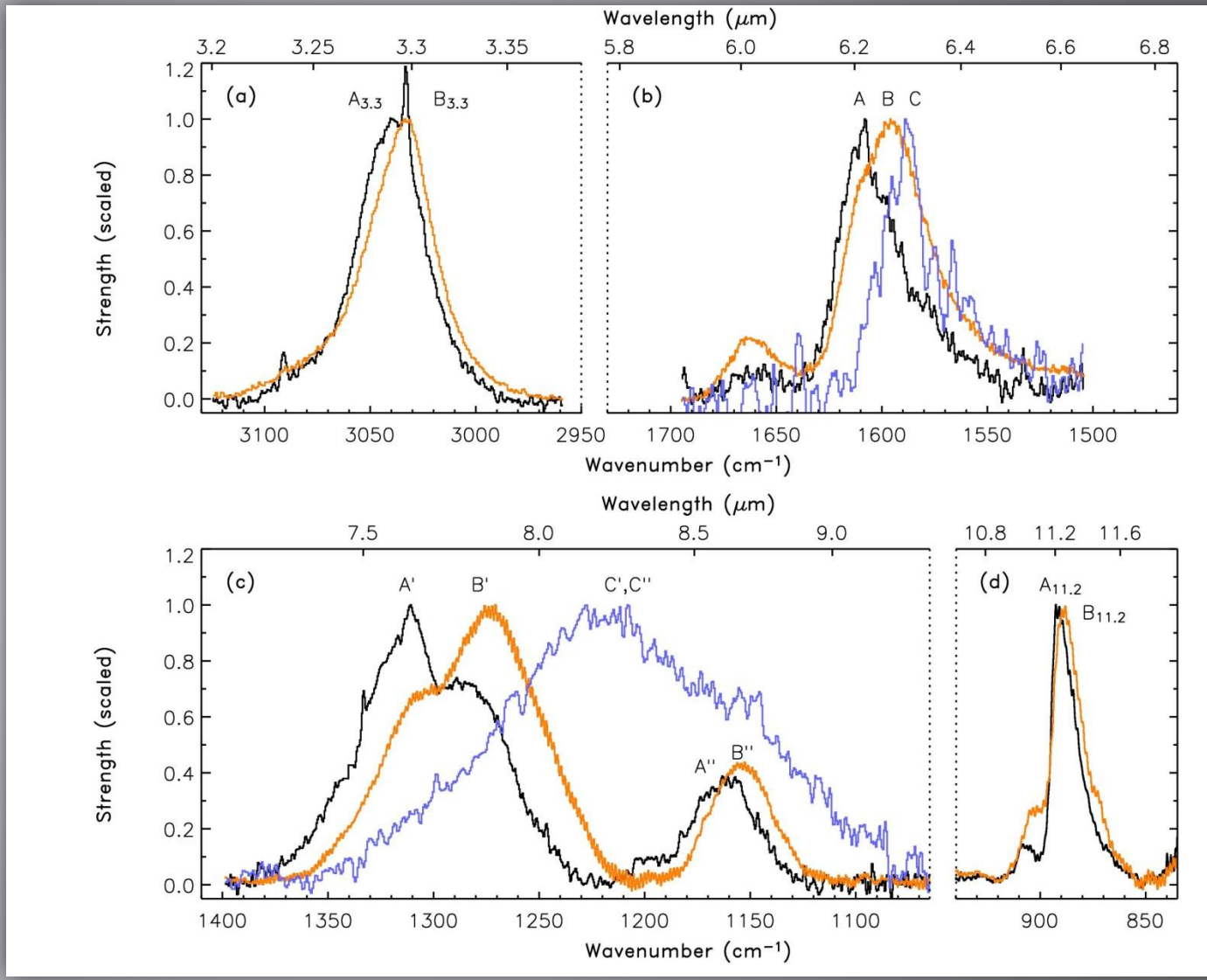


Calzetti et al. '07

PAH band profiles

- Class A, B, C
- Class B:

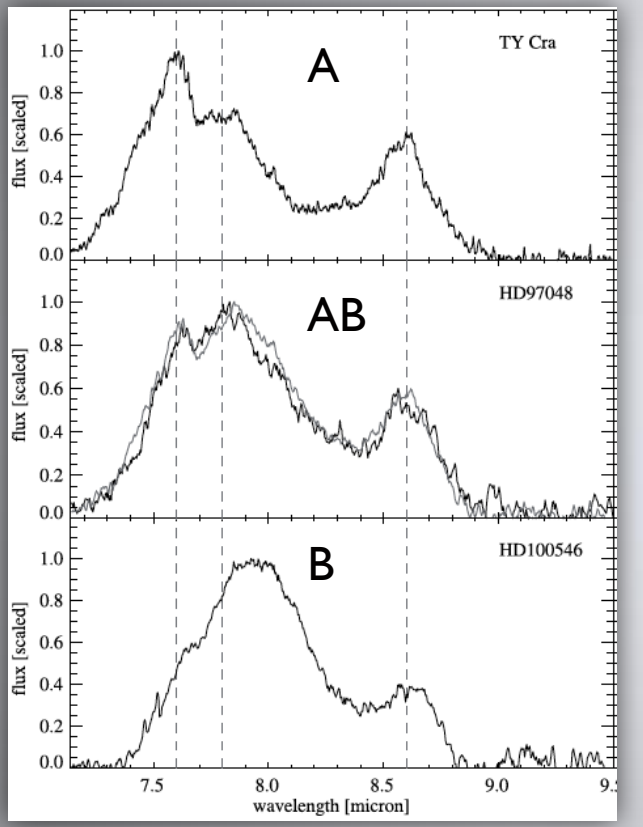
  highly variable



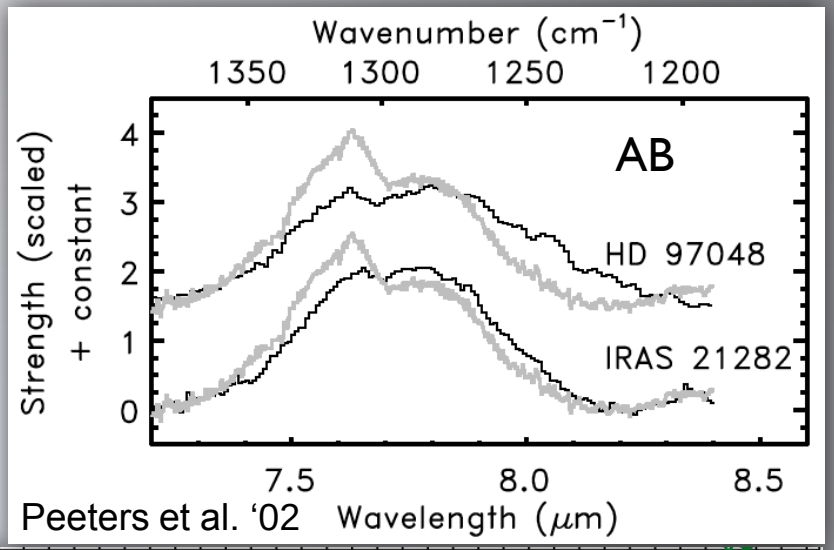
Peeters et al. ‘02, van Diedenhoven et al. ‘0

PAH band profiles

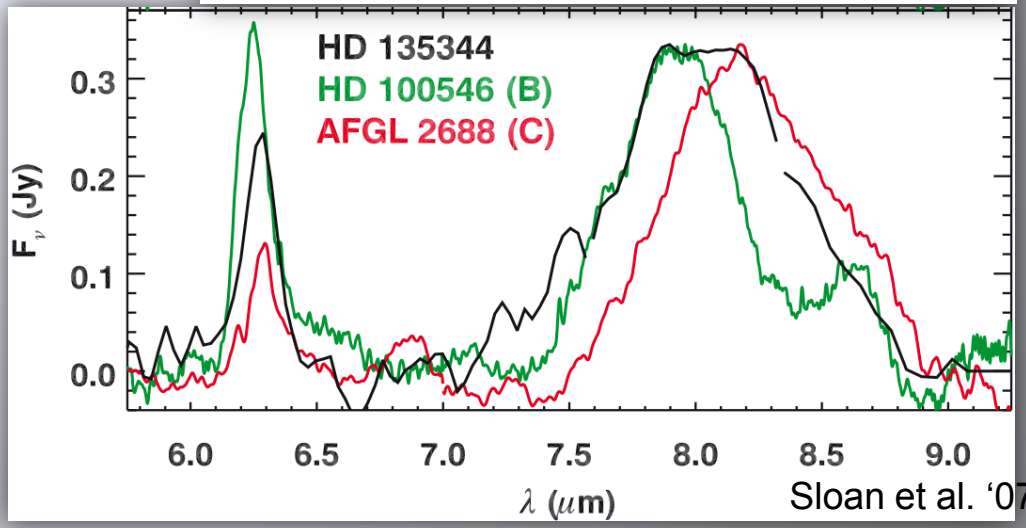
- Continuous distribution: A → B → C



Boersma et al. ‘08



Peeters et al. ‘02



Sloan et al. ‘07

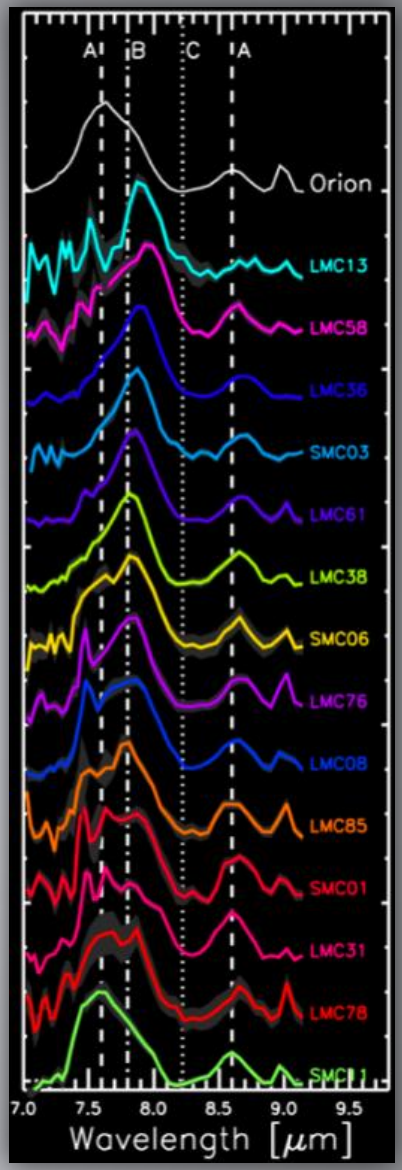
PAH band profiles

- Observed in Milky Way – LMC – SMC
- Class linked to object type:
  - Class A: interstellar material

    -- HII regions, reflection nebulae, ISM
    (few post-AGB stars, planetary nebulae)
  - Class B: circumstellar material

    -- post-AGB stars, most planetary nebulae,
    HAeBe stars
  - Class C: circumstellar material

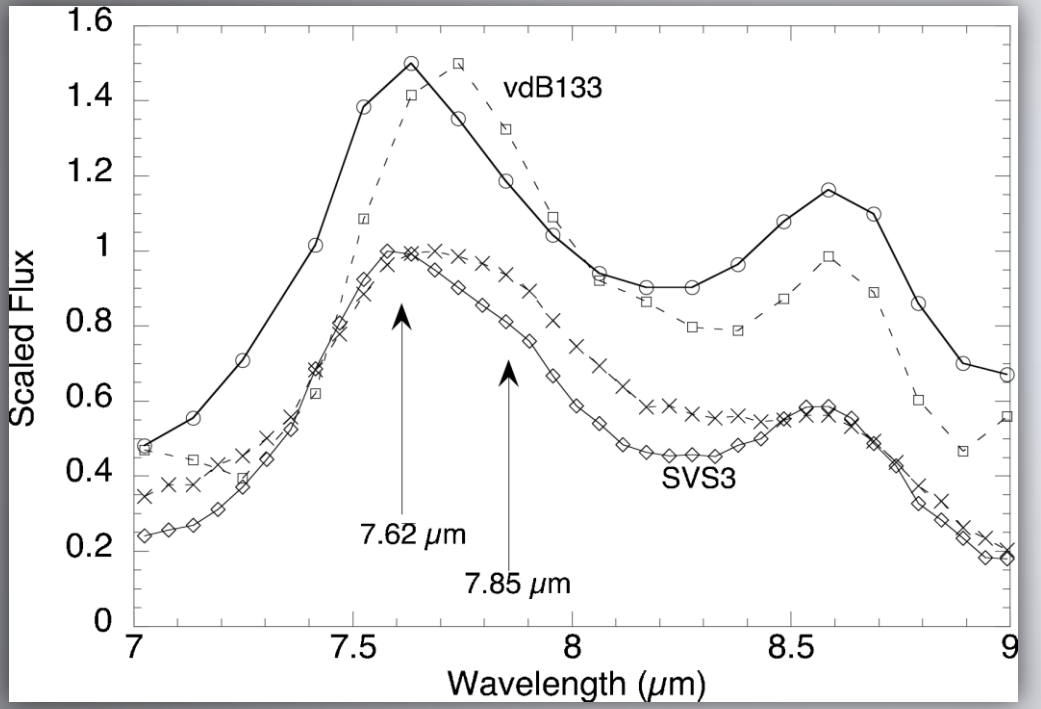
    -- post-AGB stars (few HAeBe stars &TTauri stars)



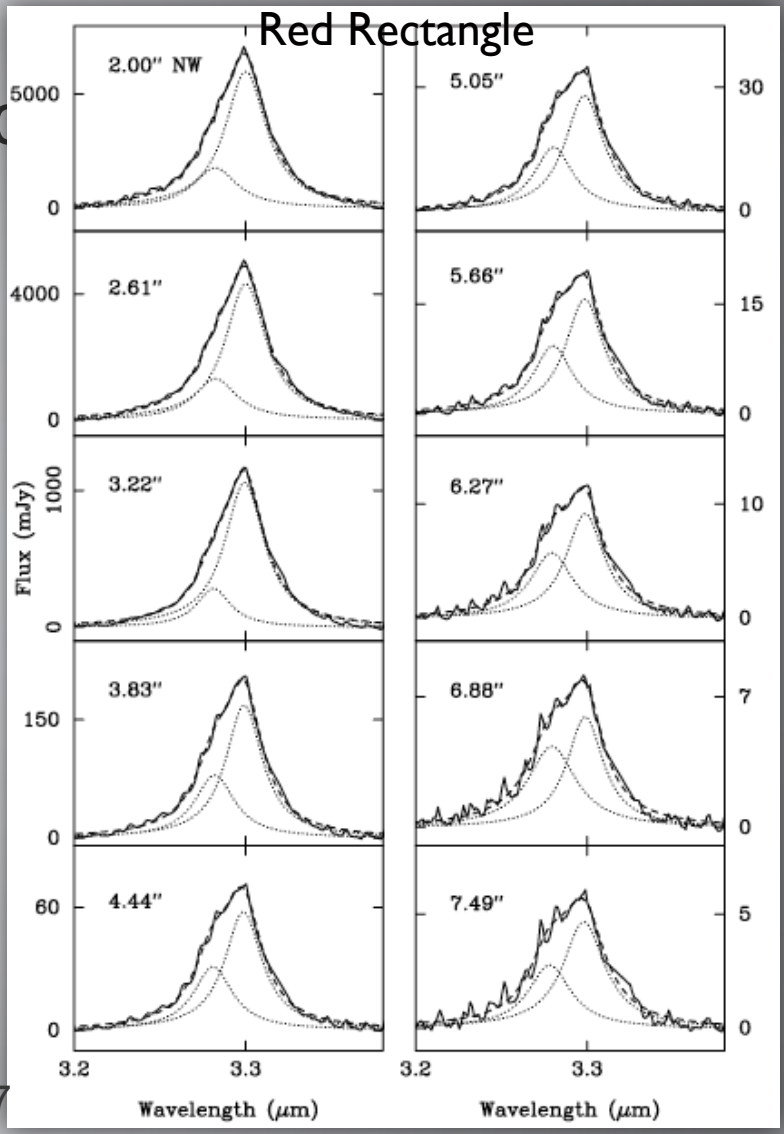
Bernard-Salas et al. '09

PAH band profiles

- Variation within extended sourc



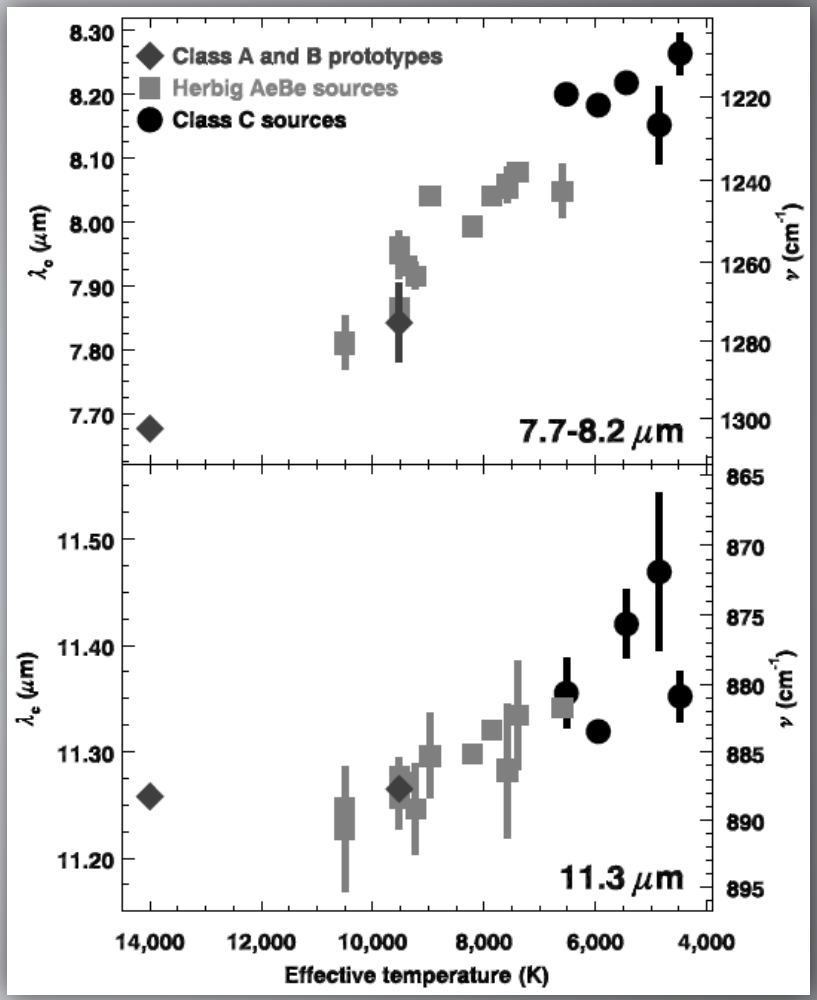
Bregman et al. ‘05



Song et al. ‘07

PAH band profiles

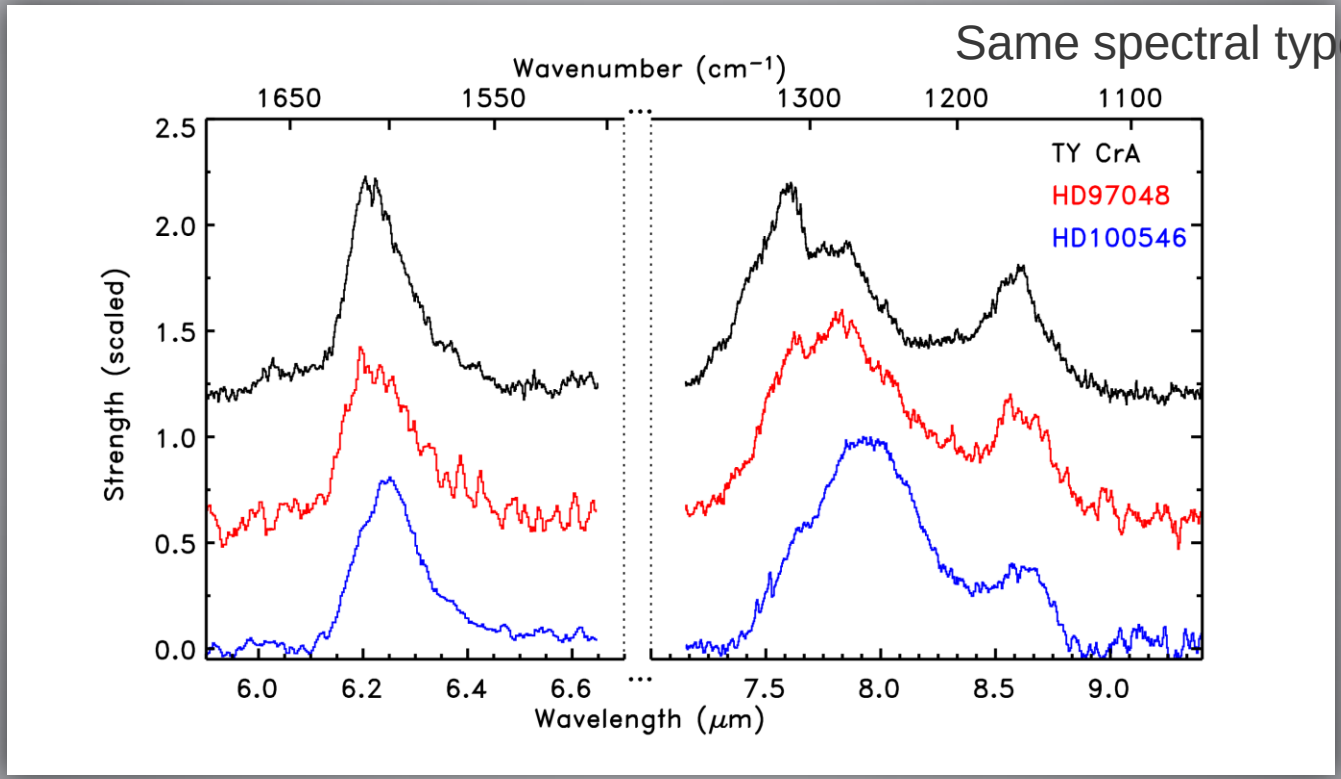
- position of classes (B/C) versus T_{eff}
  (not all sources shown)
- reflection nebulae: class A
  (e.g. Uchida et al. '00)
- CSM versus ISM



Sloan et al. '07, Keller et al. '08

PAH band profiles

- CSM (HD100546) versus ISM (TY Cra)



Van Kerckhoven ‘02, Boersma et al. ‘08

PAH band profiles

- variations reflect chemical modification

- proposed interpretations:
  - hetero-atom substituted PAHs

    (e.g. Peeters et al. ‘02, Hudgins et al. ‘05, Bauschlicher et al. ‘09)
  - PAH-metal complexes

    (e.g. Hudgins et al. ‘05, Bauschlicher et al. ‘09, Simon &Joblin ‘07, ‘10, Joalland et al. ‘09)
  - PAH clusters

    (e.g. Peeters et al. ‘02, Rapacioli et al. ‘05, Simon &Joblin ‘09)
  - carbon isotope effects

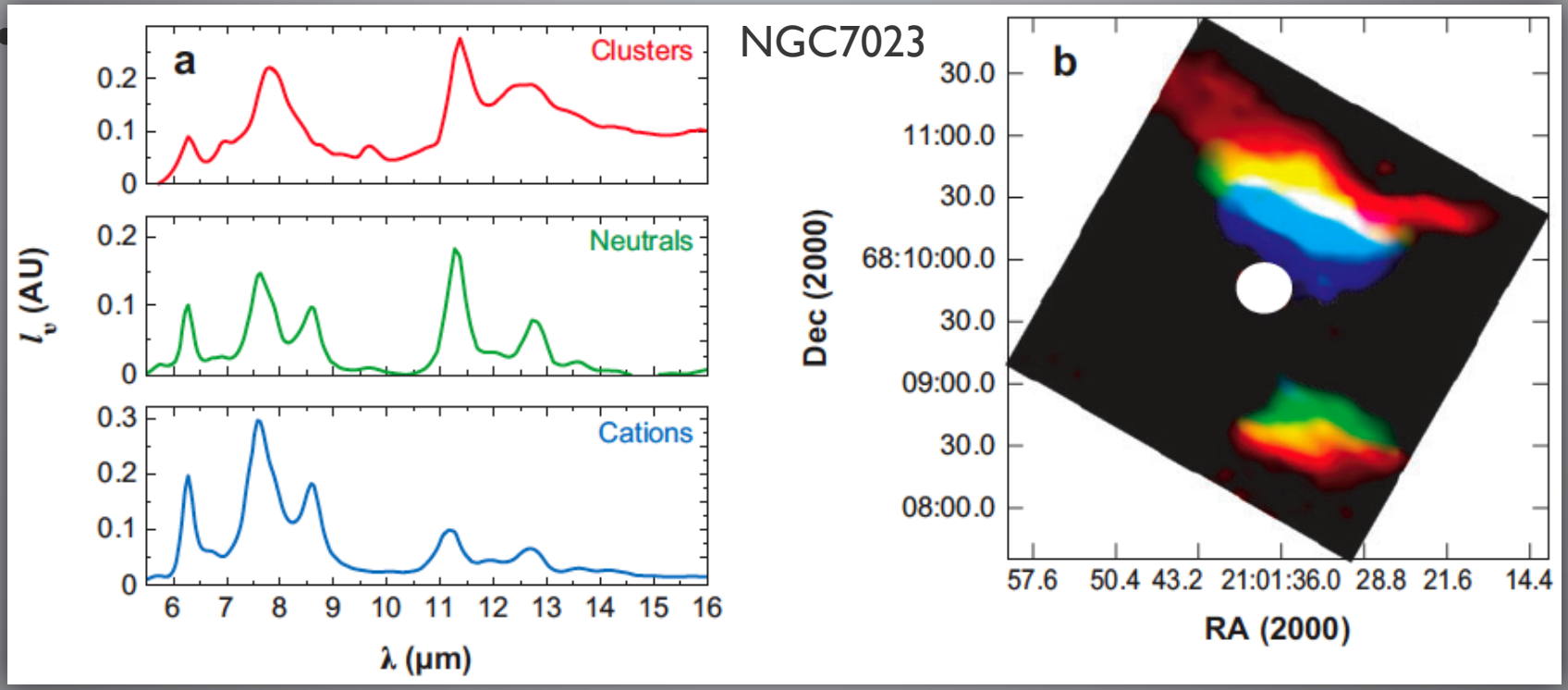
    (Wada et al. ‘08)
  - aliphaticsvs aromatic

    (e.g. Sloan et al. ‘07, Pino et al. ‘08)
  - PAH size

    (e.g. Bauschlicher et al. ‘08, ‘09)

Spectral decomposition

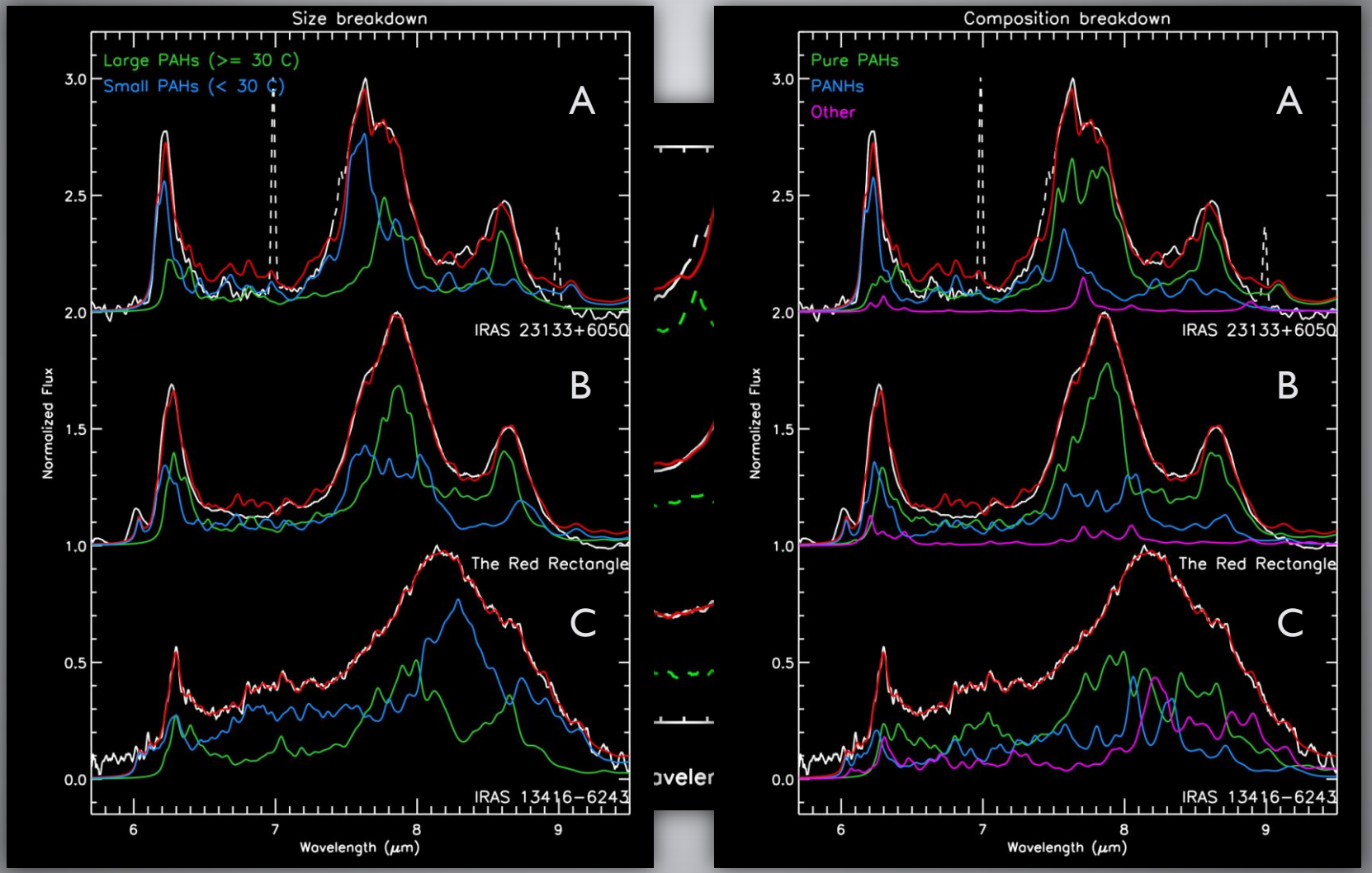
- Singular value decomposition: separate components with different spatial distributions
- PAH^0, PAH^+, VSGs (i.e. clusters), BF8, BF12, PAH^x, dBF



Rapacioli et al. ‘05, Berné et al. ‘07, ‘08, ‘09, Joblin et al.

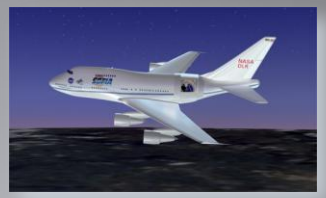
Spectral fitting

- Fit with NASA Ames PAH Database

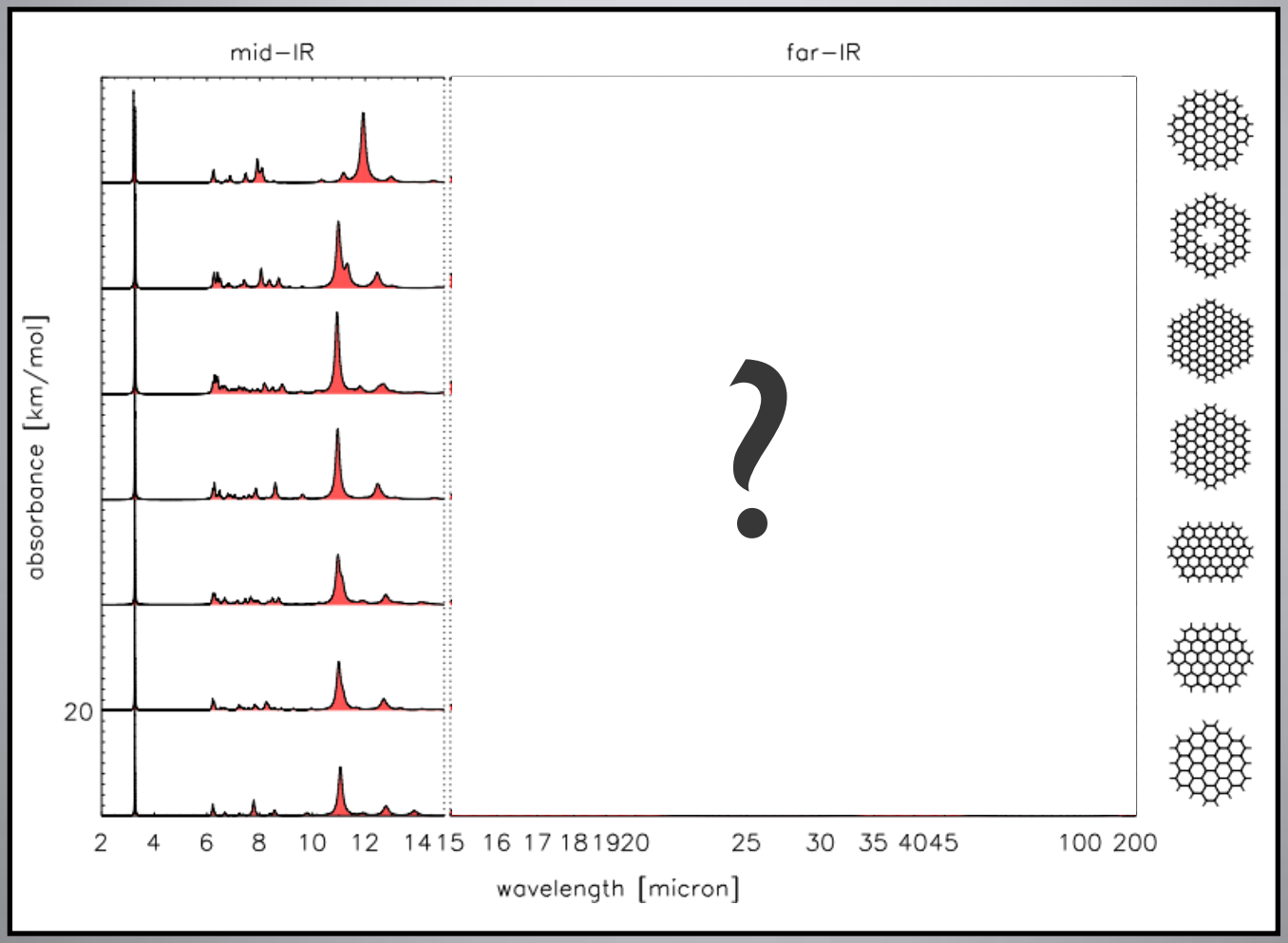


Cami et al., ’11

New horizons



Far-IR modes more molecule specific



Malloci et al. '07
Mattiodaet al. '09
Ricca et al. in '10
Zhang et al. '10
Boersma et al. '11
Joblin '11
etc.

PAH hypothesis

- Still alive and kicking
- PAHs: not strict chemical definition
  - Impurities
  - Clusters
  - …

Summary

Proceedings conference: “PAHs and the Universe”

EAS Publications Series, Vol. 46, 2011

- Rich PAH spectrum
- Variations in PAH intensities and profiles
- Variations depend on object type, local conditions
- Variations reflect change in composition of the carriers
- PAH toolbox
- Future is bright